REMARKS

Claims 8-9, 11-14, and 35-47 stand rejected on prior art grounds. Applicants respectfully traverse these rejections based on the following discussion. Additionally, the limitations of previously presented claims 37 and 43 are amended into their respective independent claims. Thus, claims 37 and 43 are cancelled and claims 8-9, 11-14, 35-36, 38-42 and 44-47 are all the claims presently pending in the application.

I. The Prior Art Rejections

Claims 8-9, 35, 37-39, 42-43, and 46 stand rejected under 35 U.S.C. §102(b) as being anticipated by Hite, et al. (U.S. Patent No. 4,863,878), hereinafter referred to as Hite. Claims 11-14, 36, and 40-41 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Hite, in view of Thompson, et al. (U.S. Patent No. 6,020,244), hereinafter referred to as Thompson and Noguchi, et al. (U.S. Publication No. 2004/0135210), hereinafter referred to as Noguchi. Claims 44-45 and 47 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Hite, in view of Noguchi. Applicants respectfully traverse these rejections based on the following discussion.

A. Rejection Independent Claim 35 Based On Hite

The Applicants submit that Hite does not teach or suggest the following features of amended independent claim 35: (1) "wherein said silicon substrate comprises an oxidized portion directly adjacent said epitaxial silicon layer" and (2) "wherein said oxidized portion has an oxygen content below an amount which would prevent epitaxial growth of said epitaxial silicon layer from said oxidized portion and further above an amount required to substantially limit dopants within said epitaxial silicon layer from moving into said silicon substrate."

Specifically, Hite discloses methods of forming silicon on insulator (SOI) structures (i.e., a structure with a pure silicon layer on and insulator layer). The background section of Hite (see col. 1, line 40-col. 2, line 2 and Figures 1A-1D) discusses a prior art method of forming a SOI structure. Specifically, referring to Figures 1A-1D, oxygen ions are implanted into a silicon substrate 1 with an energy sufficient to cause implantation below the top surface of the substrate. During this implant process, the oxygen ions react with the substrate to form a silicon dioxide layer 3 below a crystalline silicon layer 5 of the substrate. The structure is then subjected to a high temperature anneal in order to anneal the damage caused to the crystalline silicon layer 5 in the substrate and to provide a good base for forming an crystalline epitaxial layer 7 on the surface of the crystalline silicon layer 5.

Hite's invention is similar to this prior art process but eliminates the anneal process (see col. 2, line 40-col. 3 line 16). Specifically, Hite indicates that the prior art is susceptible to radiation effects and discloses that omitting the anneal step has some advantageous results. That is, referring to Figures 2A-2D, Hite's invention discloses that a silicon substrate 21 undergoes a high dose, high energy oxide ion implant (e.g., 150 keV-200keV and 1.1 x $10^{18}/cm_2$ - 2.2 x $10^{18}/cm^2$) such that a buried silicon dioxide layer 23 is formed below a silicon top surface 25. The temperatures during the implant are kept between 400 and 600 degrees so as to maintain the crystallinity of the silicon surface 25. The anneal step is omitted and an epitaxial layer 27 is grown by CVD on the single crystalline silicon surface 25.

Contrarily, in one embodiment of the present invention (as claimed in claim 35) the top surface of the substrate is oxidized such that the oxygen content at the top surface is higher than any other portion of the substrate, but below an amount which would prevent epitaxial growth of

an epitaxial silicon layer from that oxidized portion (see paragraphs [0022]-[0023]). For example, the top 50%, the top 10% or the top 1% can be oxidized using a low dose, low energy implant (e.g., 0.1keV -20keV and 1.1 x $10^{15}/cm_2$ - 2.2 x $10^{17}/cm^2$). The structure further comprises an eptiaxial silicon layer grown from the oxidized portion at the top surface of the substrate (see paragraph [0025]). This is followed by conventional FET processing (e.g., gate stack formation on the epitaxial silicon layer and dopant implants) (see paragraph [0026]-[0027]). It should be noted that the oxygen content of the oxidized portion, while being below an amount that would prevent epitaxial growth of the epitaxial silicon layer, is still above an amount required to limit the dopants in the epitaxial silicon layer from moving into the silicon substrate (see paragraph [0027]).

The Office Action provides that Hite teaches "a silicon substrate 1, wherein the top surface of said silicon substrate has an increased oxygen content which would prevent epitaxial growth from said silicon substrate (see epitaxial layer 7 or 9 or 27 is able to grow thereon); A silicon layer 9 directly on said top surface of the silicon substrate, the silicon layer comprising dopants (source/drain); wherein said dopants inherently are substantially limited to said silicon layer by said amount of oxygen content 3 of said top surface of said silicon substrate." The Applicants respectfully disagree.

As discussed above, Hite discloses that oxygen is implanted below the surface of a silicon substrate such that the substrate itself comprises a crystalline silicon layer at the top surface (see item 5 of Figure 1A or item 25 of Figure 2A) with a buried oxide layer underneath this silicon layer (see item 3 of Figure 1A or item 23 of Figure 2A). Specifically, col. 1, lines 40-51, of Hite refers to Figure 1A and discloses "Oxygen ions are implanted into the surface of substrate 1 with

energy sufficient to cause implantation below crystalline region 5. These ions react with substrate 1 to form silicon dioxide layer 3 with crystalline silicon layer 5 on the surface." Thus, the structure in Figure 1A of Hite is a solid substrate separated into layers or portions as a result of an oxygen implantation process. The top portion of the substrate 1 is a crystalline silicon portion 5 and an implanted buried oxide portion 3 is below the top crystalline silicon portion 5. An epitaxial layer 7 is grown from the non-oxygen containing crystalline silicon portion 5. It should be noted that, while the subsequent figures (i.e., see Figures 1B-1D) do not continue to show the top silicon portion 5, it is clear from the description in the text that this top silicon portion 5 of the substrate 1 remains intact and the epitaxy process is performed so that the epitaxial layer 7 is grown from the top silicon portion 5 of the substrate 1. Item 9 refers to the remaining portion (i.e., mesa) of epitaxial layer 7 after it is etched. Figures 2A-D of Hite refer to a similar structure that is formed without an anneal step. Thus, nowhere in Hite does it teach or suggest an oxidized portion of a substrate directly adjacent to an epitaxial silicon layer on the top surface of the substrate.

Additionally, as mentioned above, after epitaxial layer 7 is formed on the top silicon portion 5 of the substrate 1, it is patterned and etched to form a mesa structure 9. Mesa 9 is then doped to form source/drain regions (see col. 1, lines 50-65 and col. 3, lines 18-48). Since non-oxygen containing top silicon portion 5 of the substrate 1 is necessarily present between mesa 9 and buried oxide portion 3, there is nothing to prevent the source/dopants in the mesa from diffusing or being implanted through into the top silicon portion 5 of the substrate 1. That is, while the buried oxide portion 3 of Hite would inherently prevent the spread of dopants into the lower portion of the silicon substrate 1 (i.e., below the buried oxide portion 3), it would do

nothing to limit such dopants from moving from the epitaxial layer 7 itself into the top silicon portion 5 of the silicon substrate 1. Again, Figures 2A-D of Hite refer to a similar structure that is formed without an anneal. Thus, Hite does not teach or suggest "wherein said oxidized portion has an oxygen content ... above an amount required to substantially limit dopants *within said epitaxial silicon layer from moving into said silicon substrate*."

Therefore, amended independent claim 35 is patentable over Hite. Further, dependent claims 36 and 38-41 are similarly patentable, not only by virtue of their dependency from a patentable independent claim, but also by virtue of the additional features of the invention they define. Moreover, the Applicants note that all claims are properly supported in the specification and accompanying drawings, and no new matter is being added. In view of the foregoing, the Examiner is respectfully requested to reconsider and withdraw the rejections.

B. Rejection Independent Claims 8 and 42 Based On Hite

The Applicants submit that Hite does not teach or suggest the following features of amended independent claim 8 or the similar features of amended independent claim: (1) "a gate stack on a top surface of said silicon substrate;" (2) "a recess in said silicon substrate at said top surface adjacent said gate stack;" (3) "an epitaxial silicon layer in said recess on said silicon substrate, grown from said silicon substrate and comprising dopants;" (4) "wherein said silicon substrate comprises an oxidized portion bordering said recess directly adjacent said epitaxial silicon layer;" and (5) "wherein said oxidized portion has an oxygen content below an amount which would prevent epitaxial growth of said epitaxial silicon layer from said oxidized portion

and further above an amount required to limit said dopants within said epitaxial silicon layer from moving into said silicon substrate."

More particularly, in another embodiment of the present invention (as claimed broadly in claim 8 and more narrowly in claim 42) a gate stack is formed on the top surface of a silicon substrate and then recesses are formed in the top surface of the substrate adjacent to the gate stack (see paragraphs [0028]-[0029]. Once the recesses are formed the exposed surfaces of the substrate are oxidized, as described above in the earlier embodiment (see paragraph [0030]). Thus, as illustrated in Figure 6, the oxidized portion of the substrate borders the recess. The structure further comprises an eptiaxial silicon layer grown in the recess directly adjacent (i.e., grown from) the oxidized portion of the substrate (see paragraph [0030]-[0031]). Specifically, multiple epitaxial layers (e.g., an epitaxial halo layer and an epitaxial source/drain layer) can be grown in the recess on the oxidized portion of the substrate nd either in-situ doped or subsequently doped. Again, the oxygen content of the oxidized portion, while being below an amount that would prevent epitaxial growth of the epitaxial silicon layer, is still above an amount required to limit the dopants in the epitaxial silicon layer from moving into the silicon substrate.

Hite teaches a gate 33, however, the gate 33 is formed on an epitaxial layer 7 (i.e., on epitaxial mesa 9) and not on the silicon substrate 1 itself. Additionally, nowhere in Hite does it teach or disclose a recess in the silicon substrate adjacent the gate. Thus, Hite necessarily also does not teach or suggest an epitaxial silicon layer grown in such a recess.

Additionally, as to the claimed features of "wherein said silicon substrate comprises an oxidized portion bordering said recess directly adjacent said epitaxial silicon layer;" and "wherein said oxidized portion has an oxygen content below an amount which would prevent

epitaxial growth of said epitaxial silicon layer from said oxidized portion and further above an amount required to limit said dopants within said epitaxial silicon layer from moving into said silicon substrate", the same arguments set out above with regard to claim 8 apply.

That is, Hite discloses oxygen implanted below the surface of a silicon substrate such that the substrate itself comprises a crystalline silicon layer at the top surface (see item 5 of Figure 1A or item 25 of Figure 2A) with a buried oxide layer underneath this silicon layer (see item 3 of Figure 1A or item 23 of Figure 2A). The epitaxial layer 7 (i.e., mesa 9) of Hite is grown from the non-oxygen containing crystalline silicon portion 5. Thus, nowhere in Hite does it teach or suggest an oxidized portion of a substrate directly adjacent to an epitaxial silicon layer (as it is in the recess of the claimed invention). Furthermore, while the buried oxide portion 3 of Hite would inherently prevent the spread of dopants into the lower portion of the silicon substrate 1 below the buried oxide portion 3, it would do nothing to limit such dopants from moving from the epitaxial layer 7 itself into the top silicon portion 5 of the silicon substrate 1. Thus, Hite does not teach or suggest "wherein said oxidized portion has an oxygen content ... above an amount required to substantially limit dopants *within said epitaxial silicon layer from moving into said silicon substrate*."

Therefore, amended independent claims 8 and 42 are patentable over Hite. Further, dependent claims 9, 11-14, and 44-47 are similarly patentable, not only by virtue of their dependency from a patentable independent claim, but also by virtue of the additional features of the invention they define. Moreover, the Applicants note that all claims are properly supported in the specification and accompanying drawings, and no new matter is being added. In view of the foregoing, the Examiner is respectfully requested to reconsider and withdraw the rejections.

C. Rejection Of Dependent Claims 11-14, 36, 40-41, 44-45 and 47 Based On Proposed Combinations Of Hite, Thompson and/or Noguchi.

The Applicants submit that, as discussed above, Hite alone does not teach or suggest the independent claims. Furthermore, the Applicants submit that Hite in combination with the other cited prior art references (Thompson and/or Noguchi) also does not teach or suggest the independent claims. Thus, the rejection of all dependent claims 9, 11-14, 36, 38-41 and 44-47, should also be removed, not only based on dependency from a patentable independent claim, but also based on the additional features of the invention they define.

More particularly, claims 11 and 44 include the feature of "wherein said silicon substrate includes a column portion adjacent said epitaxial silicon halo layer and said epitaxial silicon source/drain layer (or said epitaxial silicon layer in the case of claim 44), wherein said column portion is below said gate stack." Furthermore, claims 13 and 40 include the feature of "isolation regions in said epitaxial silicon layer and said silicon substrate." The Office Action Acknowledges these features are not taught by Hite. Thus, the Office Action provides that Noguchi teaches these features. The Applicants respectfully disagree.

Furthermore, the Applicants submit that Noguchi also does not teach or suggest the features in independent claim 35 of : (1) "wherein said silicon substrate comprises an oxidized portion directly adjacent said epitaxial silicon layer" and (2) "wherein said oxidized portion has an oxygen content below an amount which would prevent epitaxial growth of said epitaxial silicon layer from said oxidized portion and further above an amount required to substantially limit dopants within said epitaxial silicon layer from moving into said silicon substrate." Nor does Noguchi teach or suggest the features in independent claims: (1) "a recess in said silicon

substrate at said top surface adjacent said gate stack;" (2) "an epitaxial silicon layer in said recess on said silicon substrate, grown from said silicon substrate and comprising dopants;" (3) "wherein said silicon substrate comprises an oxidized portion bordering said recess directly adjacent said epitaxial silicon layer;" and (4) "wherein said oxidized portion has an oxygen content below an amount which would prevent epitaxial growth of said epitaxial silicon layer from said oxidized portion and further above an amount required to limit said dopants within said epitaxial silicon layer from moving into said silicon substrate." Specifically, per the Abstract and paragraphs [0045] and [0129], Noguchi teaches a transistor formed in a strain effect semiconductor layer in an upper layer of a semiconductor substrate. A gate electrode 13 is positioned on the substrate. Additionally, implanted source/drain regions 14, 15 are located within the substrate on either side of the gate electrode. Nowhere in Noguchi is an oxidized portion of the substrate (as claimed in the independent claims) taught or suggested.

Claims 12 and 36 refer to halo dopants that are different from source/drain dopants. Thompson is only offered for the purpose of teaching halo dopants different from source/drain dopants. The Applicants respectfully disagree.

Furthermore, the Applicants submit that Thompson also does not teach or suggest the features in independent claim 35 of : (1) "wherein said silicon substrate comprises an oxidized portion directly adjacent said epitaxial silicon layer" and (2) "wherein said oxidized portion has an oxygen content below an amount which would prevent epitaxial growth of said epitaxial silicon layer from said oxidized portion and further above an amount required to substantially limit dopants within said epitaxial silicon layer from moving into said silicon substrate." Nor does Thompson teach or suggest the features in independent claims: features of amended

independent claim 8 or the similar features of amended independent claim: (1) "a gate stack on a top surface of said silicon substrate;" (2) "a recess in said silicon substrate at said top surface adjacent said gate stack;" (3) "an epitaxial silicon layer in said recess on said silicon substrate, grown from said silicon substrate and comprising dopants;" (4) "wherein said silicon substrate comprises an oxidized portion bordering said recess directly adjacent said epitaxial silicon layer;" and (5) "wherein said oxidized portion has an oxygen content below an amount which would prevent epitaxial growth of said epitaxial silicon layer from said oxidized portion and further above an amount required to limit said dopants within said epitaxial silicon layer from moving into said silicon substrate." Specifically, Thompson teaches "a well boosting implant which provides better characteristics than traditional halo implants particularly for short channel devices (e.g., 0.25 microns orless). In effect, an implant is distributed across the entire channel with higher concentrations in the center of the channel of the devices ..." Nowhere in Thompson is an oxidized portion of the substrate (as claimed in the independent claims) taught or suggested.

Claims 14, 41 and 45 include the feature of "wherein said top surface is essentially damage and native oxide free." The Office Action does not cite any art reference as teaching this feature.

Therefore, amended independent claims 8, 35 and 42 are patentable over the proposed combinations of Hite, Thompson and Noguchi. Furthermore, dependent claims 9, 11-14, 36, 38-41 and 44-47, are similarly patentable, not only by virtue of their dependency from a patentable independent claim, but also by virtue of the additional features of the invention they define. Moreover, the Applicants note that all claims are properly supported in the specification and accompanying drawings, and no new matter is being added. In view of the foregoing, the

Examiner is respectfully requested to reconsider and withdraw the rejections.

II. Formal Matters and Conclusion

With respect to the rejections to the claims, the claims have been amended, above, to overcome these rejections. In view of the foregoing, Applicants submit that claims 8-9, 11-14, 35-36, 38-42 and 44-47, all the claims presently pending in the application, are patentably distinct from the prior art of record and are in condition for allowance. Therefore, t he Examiner is respectfully requested to reconsider and withdraw the rejections to the claims and further to pass the above application to issue at the earliest possible time.

Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary. Please charge any deficiencies and credit any overpayments to Attorney's Deposit Account Number 09-0458.

Respectfully submitted,

Dated: November 28, 2007

/Pamela M. Riley/
Pamela M. Riley
Registration No. 40,146

Gibb & Rahman, LLC
2568-A Riva Road, Suite 304
Annapolis, MD 21401
Voice: (410) 573-0227
Fax: (301) 261-8825
Customer Number: 29154